

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO FIBRE-REINFORCED LAMINATES

(71) I, DAVID LANGFORD GILLESPIE, a citizen of the Irish Republic, Grovers Farm, Dippenhall, Farnham, Surrey, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to fibre-reinforced plaster laminae and methods for their production.

Laminae of a resin, usually polyester, reinforced with glass fibre find many applications in architecture, for example in partitions and in ceilings having a complex structure to conceal lighting and other services. Such laminae are inherently combustible and the additives that are used in order to render them fire-resistant or fire-retardant often give rise to very toxic fumes in the event of a fire; moreover, despite the properties imparted by the additives, the resin in the laminae still tends to emit a great deal of smoke when subjected to high temperatures.

Glass-fibres reinforced gypsum plasterboards, mouldings and extrusions have been proposed for constructional use, for example, in the manufacture of wall, floor, ceiling or roof structures, doors and cabinets. However, such articles were conceived apparently as substitutes for plaster board or its equivalent, and as such were of considerable thickness, which meant that not only were they heavy and dense, but also that the excess water that was necessary to achieve adequate wetting of the glass reinforcement required the use of cumbersome production techniques in order to remove it. However, the removal of water by vacuum techniques tended to draw in air and create small voids and surface blemishes. Moreover, the production techniques referred to above resulted in a poor surface finish due to denuding the surface glass of the gypsum, and among non-planar articles, could be adapted to the production

only of simple two-dimensional folded shapes.

The present invention stems from the realization that a thin sheet of reinforced plaster can have good structural properties, and that a thin sheet can be more easily produced than a thick sheet because the excess water can be removed simply by heating; moreover, it has been found that it is not necessary with a thin sheet to apply vacuum or pressure to avoid creating voids and cavities, and it is possible at the same time to use a thicker paste having a water content more nearly equal to the stoichiometric amount required for hydration.

According to one aspect of the present invention there is provided a lamina of plaster reinforced with monofilament, continuous strand glass fibre distributed substantially throughout the thickness thereof. Monofilament, continuous strand glass fibre is used rather than a conventional chopped strand mat in which bundles of filaments make-up the reinforcement.

Preferably the glass fibre is in the form of a mat. The preferred type of mat is the very thin form known as tissue which allows a fine smooth edge to be achieved on the laminate; several layers of mat are normally used. For additional strength bands of carbon fibre may be sandwiched between two layers of tissue. It has been found that the optimum amount of the reinforcement is 4% by weight.

According to a further aspect of the invention such a lamina is prepared by impregnating monofilament, continuous strand glass fibre reinforcement with a plaster slurry against a moulding surface so that the glass fibre is distributed substantially throughout the thickness of the plaster and drying the impregnated fibre reinforcement.

The fibre reinforcement may be applied to a moulding surface and the slurry applied thereto by, for example, brushing or spraying and then applying heat to dry the reinforcement thus impregnated. As a tem-

perature greater than 40°C is detrimental to the characteristics of the hydrated plaster, a temperature below this should be used.

The plaster slurry may be applied to the 5 moulding surface, the fibre reinforcement laid on the slurry and pressure applied to force the fibre reinforcement through the slurry and against the said surface.

The preferred plaster is autoclaved plaster 10 and it is preferably used with a wetting agent such as a non-foaming detergent to improve the contact of the crystals with the glass fibre and also with a drying retardant such as sodium citrate to allow the laying up process to be completed before setting starts.

While for some applications a rigid sheet is preferable, there is also provided according to a yet further aspect of the 20 present invention a thin, flexible fibre-reinforced plaster lamina. Such a flexible lamina is achieved by applying a flexing stress progressively over the cured sheet, for example by rolling the above-described thin 25 rigid lamina in one or more directions between metal press rollers so as to achieve flexion through an angle of up to about 10°. If rolling is performed in one direction only, the rolled lamina will be flexible in one 30 direction only rather in the manner of a corrugated sheet. If the lamina is rolled biaxially the lamina will be found to flex in all directions under stress. Alternatively a lamina may be stressed by the use of a vibrator applied over the surface of the moulding.

Such a flexible or stressed lamina is found to have much improved shock-resistance which provides useful protection from damage by dropping, and improved fire-resistance. The explanation for the acquisition 40 of these remarkable properties is believed to be that the bond between the interlocking hydrated gypsum crystals and the reinforcement is broken, allowing a very slight 45 relative movement between the reinforcement and the adjacent crystals when the lamina is flexed; moreover the freedom of the fibres to move slightly within the tunnels formed by the adjacent crystals allows 50 a shock to be transmitted away from the point of impact and then absorbed more easily without fracture of the material. This freedom of the fibres also appears to be responsible for the freedom from warping 55 or cracking of the unflexed material when it is subjected to thermal shock or expansion, as compared with the rigid laminate. Accordingly a stressed lamina can be used as a fire-resistant cladding on, for example, 60 a foamed glass or vermiculite panel to form a rigid sandwich.

A plurality of such laminae each rolled in one direction only can be laminated together, using a suitable adhesive such as 65 urea formaldehyde glue, such that adjacent

laminae have been rolled in planes mutually at right angles. Such a structure, which may be likened to plywood, has good fire-resistant properties and is suitable for use in fire proof safes, as cladding for fire-retardant doors etc.

As compared with a glass reinforced resin lamina the plaster lamina of the present invention has the following advantages: (1) Lower cost, the price of the raw material plaster being only about $\frac{1}{20}$ that of the resin-forming materials which are derived from oil; (2) Lower weight, the weight of the plaster lamina being about only $\frac{2}{3}$ that of a similar resin laminate and $\frac{1}{4}$ that of the known plaster laminae discussed above, and this lightness is important not only in reducing transport costs, but also in reducing building costs by lightening the load that has to be supported by the structural framework of the building; (3) Complete incombustibility, not merely fire-resistance or fire-retardance; (4) The plaster lamina may easily be drilled for screws or nailed into position; (5) The plaster lamina may readily be repaired by applying plaster using techniques that are already familiar in the building industry; and (6) The plaster lamina may be produced in a complex shape, e.g., a dome or ceiling component.

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

Figs. 1a and b illustrate two steps in a process according to the invention for making a glass fibre reinforced plaster lamina;

Fig. 2 is a schematic side view of a glass-fibre reinforced lamina according to the invention, and

Fig. 3 is a schematic side view of apparatus for rolling a lamina to achieve flexion through a small angle.

Referring to Figs. 1a, b and 2 to make a plane plaster lamina 10, a layer of monofilament, continuous strand glass fibre tissue 110 12 is unrolled from a stock roll 12a and is placed on a plane moulding surface 14. A layer of thick slurry 16 formed from "Crystalcil" (trademark) autoclave plaster and incorporating a wetting agent such as a non-foaming detergent and a setting retardant or, in the case of a small moulding, an accelerator, such as sodium citrate is then sprayed thereover from a spray gun 18. The slurry is then forced into the interstices 115 of the glass fibre mat 12 by means for example of a squeegee or doctor blade 20. A further layer of tissue 12 is then placed on the slurry-impregnated first layer, followed by a further application of plaster 120 slurry. This process is then repeated three more times, and it will have been inferred that the process is similar to the laying up of a glass fibre reinforced resin lamina. The final layer of tissue, however, is not 125 130

- impregnated with slurry but is allowed to absorb the plaster from previous layers. The grade of the fibre glass mat 12 is preferably less than about 0.5 ounces per square foot.
- If desired, bands of carbon fibres about 2 inches wide and 3 inches apart may be placed between two layers of tissue. When the laying up has been completed, the plaster is dried by the application of heat using fan heaters, care being taken not to allow the temperature of the layer to exceed 40°C. When the layer 10 is removed from the moulding surface it will be found that the moulded surface is completely smooth despite the fact that the reinforcement was positioned before the plaster was applied, and that the other, unmoulded surface is of acceptable smoothness.
- By applying the reinforcement to the mould surface first maximum strength is achieved because the very skin is reinforced as opposed to a conventional plaster or fibre glass lamina which has an unreinforced layer which is subject to crazing or stress cracking, a disadvantage which is eliminated by the present invention. The reinforced skin on the back of the lamina formed by the final layer of tissue endows the lamina with a structure corresponding to that of an I-section girder.
- In another method according to the invention, a layer of plaster slurry 16 is spread over the moulding surface 11, a monofilament, continuous strand, fibre glass mat is laid over the layer of plaster slurry and is then forced through the slurry to achieve, in effect, a lamina similar to that obtained with the method described with reference to Figs. 1a and b.
- If a smooth surface is required on both sides this can be achieved by subsequently applying a moulding surface under pressure after laying up has been completed.
- A rigid plaster lamina about $\frac{1}{4}$ inch thick is produced by the above-described procedure. It may be endowed with flexibility by using the rolling technique described earlier. If carbon fibres are incorporated it is preferred not to roll the lamina in the direction of the fibres.
- Fig. 3 shows a schematic view of apparatus for rolling a lamina 10 between counter-rotating metal press rollers 22a and b and under a guide roller 24 whereby the lamina 10 is flexed downwardly (in the drawing) through an angle of up to about 10° and then upwardly between rollers 26 and 28 through a similar angle of up to about 10°. After the lamina 10 has passed through the various rollers it is found to be flexible in one direction in the manner of a corrugated sheet. If the lamina 10 is rolled biaxially it is found to flex in all directions.
- WHAT I CLAIM IS:—
1. A lamina of plaster reinforced with monofilament, continuous strand glass fibre distributed substantially throughout the thickness thereof.
 2. A lamina as claimed in Claim 1, in which the glass fibre is in the form of a mat.
 3. A lamina as claimed in Claim 2, in which the fibre glass mat has a grade less than 0.5 ounces per square foot.
 4. A lamina as claimed in any one of the preceding claims and which is also reinforced with carbon fibre.
 5. A lamina according to any of the preceding claims having a thickness of not more than 5mm.
 6. A lamina according to any one of the preceding claims, in which said plaster is autoclaved plaster.
 7. A lamina of plaster reinforced with monofilament, continuous strand glass fibre substantially as hereinbefore described with reference to and as illustrated in Figs. 1 and 2 of the accompanying drawings.
 8. A flexible lamina of plaster reinforced with monofilament, continuous strand glass fibre substantially as hereinbefore described with reference to and as illustrated in Figs. 1, 2 and 3 of the accompanying drawings.
 9. A method of preparing a plaster lamina comprising impregnating monofilament, continuous strand glass fibre reinforcement with a plaster slurry against a moulding surface so that the glass fibre is distributed substantially throughout the thickness of the plaster and heating the impregnated reinforcement to dry it.
 10. A method as claimed in Claim 9, wherein the plaster is autoclaved plaster.
 11. A method as claimed in Claim 9 or 10, wherein the fibre is in the form of a mat which is applied to the moulding surface and subsequently impregnated with plaster slurry.
 12. A method as claimed in Claim 9 or 10, wherein a plaster slurry is applied to the moulding surface, a fibre mat is laid on the slurry and pressure applied to force the mat through the slurry and against the said surface.
 13. A method as claimed in Claim 11 or 12, wherein a second mat is applied to the impregnated first-mentioned mat and the second mat then impregnated with plaster slurry, the steps of applying and impregnating further mats being repeated as necessary until a lamina of the desired thickness has been achieved, the fibre being distributed substantially throughout the thickness of the plaster.
 14. A method as claimed in Claim 11, 12 or 13, wherein a final finishing layer of fibre mat is impregnated by allowing it to absorb plaster already applied to the underlying mat.

15. A method of preparing a plaster lamina reinforced with monofilament, continuous strand glass fibre substantially as hereinbefore described with reference to 5 Figs. 1 and 2 of the accompanying drawings.
16. A plaster lamina when prepared by a method as claimed in any one of Claims 9 to 15.
- 10 17. A method according to any one of Claims 9 to 15 further comprising the step of subjecting the fibre-reinforced plaster lamina to stress.
18. A method as claimed in Claim 17, 15 wherein the stress is applied by vibrating the lamina.
19. A method as claimed in Claim 17, 20 wherein the stress is applied by rolling the lamina in at least one direction to cause flexion.
20. A method as claimed in Claim 19, wherein the flexion is through an angle up to about 10°.
21. A method of preparing a flexible 25 lamina substantially as herein described.
22. A flexible lamina when prepared by a method as claimed in any one of Claims 17 to 20.
23. A composite laminate comprising at least two laminae prepared by the method of Claim 19 bonded together such that adjacent laminae have been rolled in directions mutually at right angles. 30
24. A composite structure comprising at least two laminae as claimed in any one of Claims 1 to 8, 16, 22 and 23. 35
25. A lamina as claimed in any one of Claims 1 to 8, 16, 22, 23, 24 being a ceiling component.
26. A door or wall panel provided on its two major surfaces with a lamina as claimed in any one of Claims 1 to 8, 16, 22, 23 and 24. 40

GEE & CO.,
Chartered Patent Agents,
Chancery House,
Chancery Lane,
London WC2A 1QU,
and
39, Epsom Road,
Guildford, Surrey.
Agents for the Applicants.

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COMPLETE SPECIFICATION

2 SHEETS

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the Original on a reduced scale.

SHEET 1

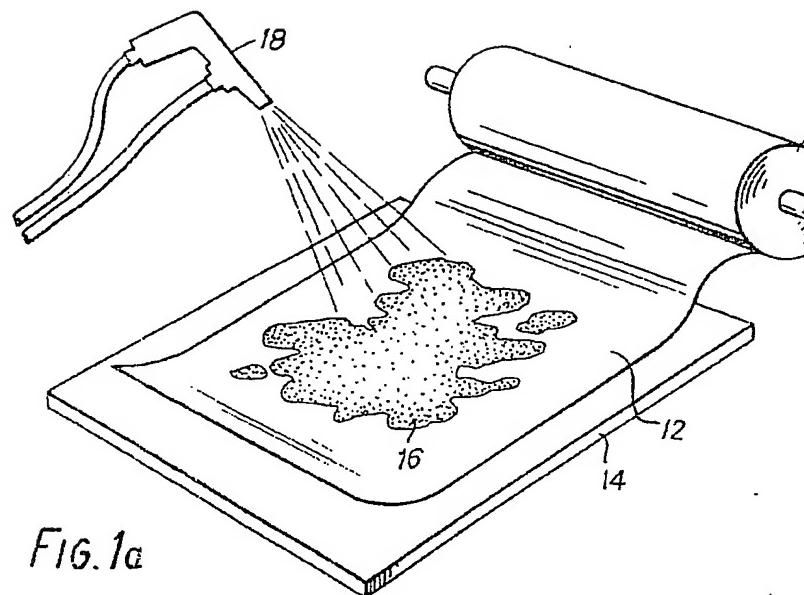


FIG. 1a

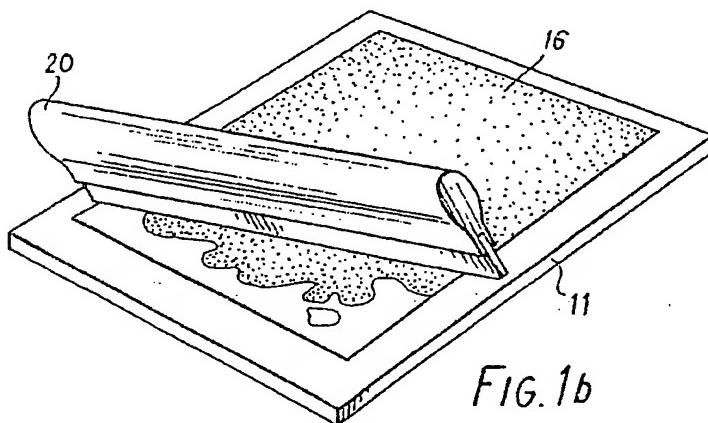


FIG. 1b

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2 SHEETS

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the Original on a reduced scale.

SHEET 2

FIG. 2

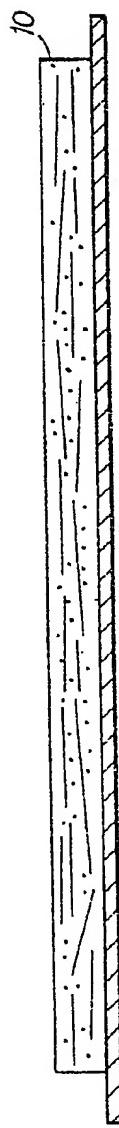


FIG. 3

